Strain enhancement of the electro-optical response in semiconductor-integrated perovskites

A. A. Demkov, **K. D. Fredrickson, A. Hamze and K. J. Kormondy**
Department of Physics, The University of Texas, Austin, TX 78712, USA

Interest in perovskite ferroelectrics such a $BaTiO_3$ (BTO) for use in nonlinear optic devices lies in its extremely large electro-optic (Pockels) coefficients >100 pm/V [1]. Even more importantly, the monolithic integration of BTO on semiconductors has paved the way to several types of entirely different devices ranging from ferroelectric memory to electro optical modulators [2-4]. Together, these developments have raised a possibility for applications of BTO in silicon nanophotonics, a hybrid technology combining semiconductor logic with fast broadband optical communications and optical information technologies.

I will discuss the possibility of significantly enhancing the nonlinear electro-optical response in strained perovskite $BaTiO_3$ and $SrTiO_3$ [5]. For $BaTiO_3$, first principles calculations predict the enhancement for both compressive and tensile strain. The physical origin can be traced to strain-induced phonon softening that results in diverging first order susceptibility. Within the Landau-Ginzburg-Devonshire formalism we demonstrate how, in turn, this divergence results in a diverging second order susceptibility and Pockels coefficient. In epitaxially strained $SrTiO_3$ the electro-optical response is calculated for biaxial strain values ranging from -2.0% to 2.0% relative to the theoretically-optimized lattice constant. Under 1.0% tensile strain, the Pockels tensor components that are zero without strain due to the centrosymmetric structure of $SrTiO_3$, increase dramatically. Experimentally, we study the nonlinear optical response in a strained thin film ferroelectric oxide $BaTiO_3$ using piezoelectric PMN-PT as a variable strain substrate and La-doped $SrTiO_3$ as a conductive buffer layer [6]. The rotation-anisotropic second harmonic intensity profile shows hysteretic modulation corresponding to strain variation from the inverse piezoelectric response of the substrate. Our results suggest a promising route to enhance the performance of nonlinear optical oxides for the development of future nano-opto-mechanical devices.

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+ Author for correspondence: demkov@physics.utexas.edu

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